ii. System Configuration

Major changes to the RHIC vacuum systems have occurred as a consequence of changes in the lattice and relaxation of the pressure requirements. Figure 4-2 shows a vacuum hardware representation of one-twelfth of the entire ring. The ~20 m warm sections previously located between the Q8 and Q9 quadrupoles have been eliminated. This resulted in the elimination of 48 all-metal valves and a similar number of TSP/Sputter-ion pump modules. However, the length of the continuous sextant cryostats has increased from ~360 m to ~480 m. Also, the present configuration reflects a warm-bore system from the end of the triplet-D0 cryostat, through DX and into the experimental regions.

Warm-Bore Sections. The warm sections are accurately represented by Fig. 4-2, which also shows the configuration for the special case at beam injection. This figure does not show the system configuration for the rf cavities or beam dump. These will be placed at selective location in the ring, probably in the warm sections subtended by the Q4 and Q3 quadrupoles.

The warm section beam pipe diameter, ~17.5 cm ϕ, has been increased to provide the needed beam aperture of the new lattice. These beam pipes will require vacuum firing at ~950°C to reduce H_2 outgassing. The warm sections will be pumped with NEG cartridge getters and sputter-ion pumps with high H_2 capacities and speeds at very low pressures.[2] This makes possible the elimination of the previously planned titanium sublimation pumps (TSPs). The equipment cost is the same, but the hidden transactions associated with the intermittent flashing and maintaining the TSPs is eliminated. For the greater part, instrumentation of the warm section comprises Bayard- Alpert gauges (BAGs) and UHV TC gauges. Provisions will exist for a 300°C, *in situ* bakeout of all warm sections, excluding the special DX and experimental region chambers. The DX chambers will also require vacuum firing at ~950°C, but, because they can not be *in situ* baked, they will have to be *in situ* glow discharge cleaned to achieve the needed outgassing rates in a reasonable time-frame. The experimental region beam pipes will also have to be in situ glow discharge

[2] K. M. Welch, et al., *The Pumping of Hydrogen and Helium by Sputter-ion Pumps*, Invited Paper, National Symposium, American Vacuum Society, Chicago, November 1992.

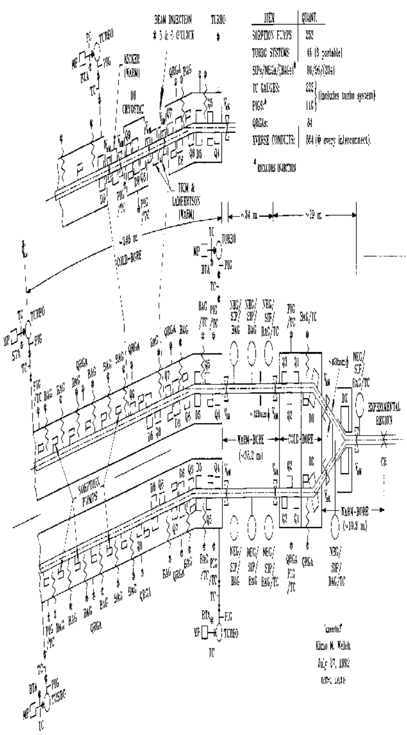

Fig. 4-2. Vacuum instrumentation and pumping for a 12th of the RHIC machine.

cleaned. Additional valves were required for isolation between the D0 and DX magnets. However, the net result of the lattice change is that 24 fewer all-metal, rf-shielded valves will be required in the warm sections.

Cold-Bore Sections. It was thought prudent in the construction of the RHIC machine to require that no welded, brazed or bolted vacuum joints serve as barriers between LHe (i.e., liquid helium) and UHV environments. This is because 4.2 K LHe-I has a factor of $\sim 10^2$ greater leak rate, in terms of molecules per second, through an equivalent RT, gaseous He leak. Liquid helium cryogen is now separately plumbed from one magnet to the next. Welded stainless steel shells, containing and aligning the magnet laminations, serve as LHe barriers from the cryostat insulating vacuum. This is a necessary compromise. However, the cold-bore comprises a seamless, austenitic stainless steel tube, extending beyond the end-plates of the magnets to which it is welded. The UHV cold-bore is interconnected between magnets with formed bellows. Therefore, the only means whereby He can leak into the cold-bore UHV system is through metallurgical flaws in the seamless pipe, because of possible damage to the pipe on welding to the magnet end-plates, or from the circumstance of gaseous He, in the cryostat, leaking through a catastrophic failure in the interconnect piping or bellows.

Several possible sources of hydrogen exist and can be pumped by the cold-bore. The primary source of H_2 in the cold-bore is due to end-effects from the warm sections and RT beam components proximate to the cold-bore (e.g., see Fig. 4-1). Roughly 50 such temperature transition regions exist in the RHIC. The transient H_2 pressure build-up in the cold-bore, due to these end effects, has been modeled.[3] For example, on opening the all-metal isolation valves separating the warm and cold sections, the H_2 pressure decreases in the beam component as suggested in Fig. 4-3. However, the H_2 pressure in the beam components increases in time and eventually equilibrates to the original pressure with the valve closed. At this time, the pressure in the proximate cold-bore is $(4.2/293)^{1/2}\ P_b$.

---

[3] J. P. Hobson, K. M. Welch, *Time-Dependent Hydrogen and Helium Pressure Profiles in a Long, Cryogenically Cooled Tube, Pumped at Periodic Intervals*, Invited Paper, National Symposium, American Vacuum Society, Chicago, November 1992.

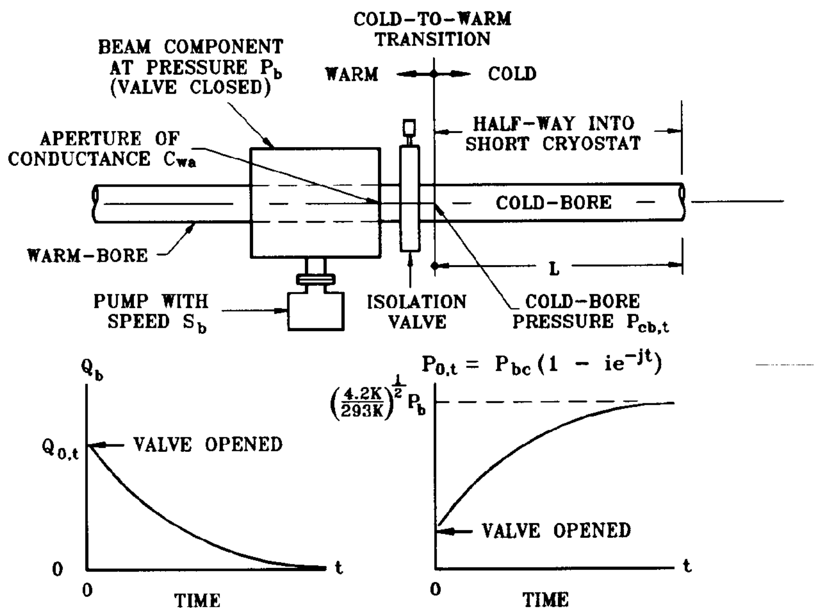

Fig. 4-3. Hydrogen pumping by the cold-bore as a function of time as a consequence of opening the warm-to-cold isolation valve.

However, the density of gas in the proximate cold-bore is $(293/4.2)^{1/2}$ higher than that in the warm-bore; the implication being that if the pressure in the proximate beam component is 2×10^{-9} Torr, in about 10 hours the equivalent pressure, in terms of H_2 gas density in the cold-bore, will be ~1.7×10^{-8} Torr.[3,4] This important consideration suggests that the cold-bore and beam component average pressure specifications may be mutually exclusive. For this reason, inequality signs are used in specifying the respective pressures. Hydrogen evolving from the dissociation of H_2O by unbaked RT instrumentation used to monitor cold-bore pressures has been shown to not be a problem. The pressure gradients stemming from possible He and H_2 leaks have been studied and reported on.[3] For the above reasons, the cold-bore tubes will be pumped with sorption pumps located at 30 m intervals. At alternate intervals of 30 m, BAGs will be coupled to the cold-bore through flexible stainless steel hoses which are brought out to the exterior of the respective cryostats. The gauging will provide a means of monitoring possible He or H_2 pressure gradients in the cold-bore, and the pumps, containing ~450 g of activated coconut charcoal, will provide a means of pumping these gases. Sputter-ion pumps were shown to be unsuitable for this purpose.[2,3]

Cryostat Vacuum Systems. All gases except He will be effectively pumped by the magnet cold masses. Even H_2 has an equilibrium vapor pressure of ~10^{-6} Torr at 4.2 K, and will therefore present no problems with the insulating vacuum. Therefore, the only problem gas will be He. Helium leaking into the cryostats may originate from two sources: 1) leaks in welds in the magnet cold mass or He interconnect plumbing; or 2) leaks from the He conduits or interconnecting bellows running the full length of the cryostats (e.g., see the Supply and Return lines of Fig. 1-4.). Two problems have been addressed: 1) locating serious He leaks to within a longitudinal resolution of one magnet interconnect; and, 2) instituting provisions for the interim, local pumping on these leaks to facilitate machine operation until repairs are implemented.

---

[4] K. M. Welch, *Capture Pumping Technology, An Introduction*, (Pergamon Press, Oxford, 1991), p. 259ff.

Excluding the He conduit bellows, the probability is greatest that a He leak will occur at magnet interconnects. For this reason, as illustrated in Fig. 4-4, a vacuum conduit will be used at every magnet interconnect to couple the interconnect region to instrumentation/ pumping ports proximately located on the magnet cryostats. Most of these ports will be capped off with inexpensive manual valves. Initially, turbopumps will be sparsely distributed along the cryostats (e.g., see Fig. 4-2). Quadrupole residual gas analyzers (QRGAs) will be similarly distributed along the cryostats. Helium pressure gradients stemming from leaks in plumbing or magnet cold-masses, will facilitate longitudinal location of these leaks. The Vacuum Instrumentation and Control System (I&C System) is sufficiently flexible so that turbopumps may be installed or relocated to pump on particularly troublesome leaks.

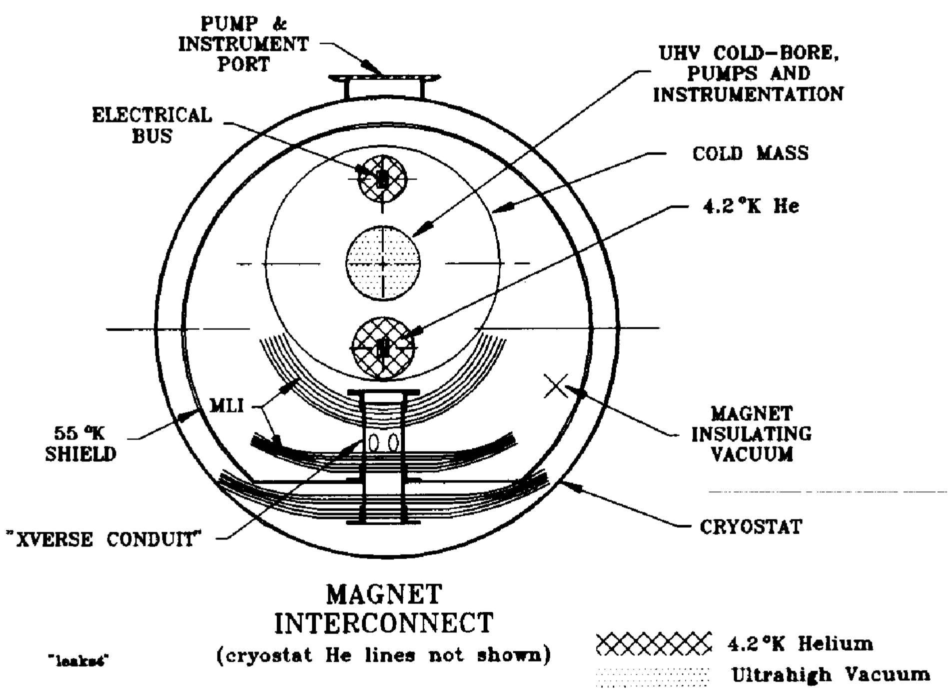

Fig. 4-4. Transverse conduit used to vacuum "couple" instrumentation or turbopumps to magnet interconnect.